Exercises HV0189 Basic Animal Breeding and Genetics

1. The chromosome number of sheep is 2n=54. How many chromosomes does a sheep sperm cell contain?

2. If the base C is located on a certain position on one of the DNA strands of chromosome 2. Which is the complementary base on the other strand?

3. At a certain position of chromosome 4 in dogs there are two alleles, *G* and *T*. One male dog with that is heterozygous *GT* is mated to a female dog that is also heterozygous *GT*. How large proportion of their offspring is expected to be homozygous *TT*?

4. The locus for orange colour in cats is located on the X chromosome. If a tortoiseshell female cat in mated to an orange male, which colours are possible in the kittens and in which proportion?

5. The locus for orange colour in cats is located on the X chromosome. If an orange female cat in mated to a black male cat, which proportion of the kittens is expected to be orange males?

6. As already mentioned in the exercises above the locus for orange colour in cats is located on the X chromosome. The locus for hair length is located on an autosomal locus. The allele for short hair, L, is dominant over the allele for long hair. A female tortoiseshell cat with long hair is mated to an orange male with short hair. The mother of the male had long hair.
a) What is the probability that a kitten is orange and has long hair?
b) What is the probability that a kitten is orange and has short hair?

7. The two loci *A* and *B* are located on the same chromosome. Locus *A* has alleles *A* and *a* and locus *B* has alleles *B* and *b*. An individual with genotype *AaBb* is mated to an individual with genotype *aabb* and they have 50 offspring with the following genotypes:
20 *AaBb*
5 *Aabb*
4 *aaBb*
21 *aabb*

What is the recombination fraction between the loci *A* and *B*?

8. The two loci *C* and *D* are located on the same chromosome. Locus *C* has alleles *C* and *c* and locus *D* has alleles *D* and *d*. An individual with genotype *CcDd* is mated to an individual with genotype *ccdd* and they have 60 offspring with the following genotypes:
11 *CcDd*
19 *Ccdd*
21 *ccDd*
9 *ccdd*
What is the recombination fraction between the loci *C* and *D*?

9. What are the forces that can change the frequency of an allele in a population?

10. At a SNP locus there are two alleles, *G* and *T*. 50 animals was gentyped for this SNP and the result was 11 with genotype *GG*, 22 with genotype *GT*, and 17 with genotype *TT*. Calculate the allele frequencies.

11. In a population of finewool sheep, 20 sheep was genotypes for a SNP marker with the alleles *A* and *T*. The following genotypes were obtained: *AA, AA, TT, TT, TT, AT, AT, AT, TT, TT, AT, AA, AT, AA, AA, AT, AT, AT, AT, AT*.
a) Calculate the genotype frequencies.
b) Calculate the allele frequencies.

12. At a microsatellite locus there are 12 alleles: A_1, A_2, A_3, A_4, ..., A_{12}. In a certain population of poultry the frequency of allele A_2 is 0.10, the frequency of allele A_3 is 0.15 and the frequency of allele A_5 is 0.07. Assume that there is Hardy-Weinberg equilibrium in the population.

a) What is the expected frequency of genotype A_2A_2?

b) What is the probability that a randomly selected individual from the population has genotype A_3A_5?

13. At a master thesis project in spring 2013 at Department of Animal Breeding and Genetics a number of samples from Swedish local chicken breeds were genotyped for 24 microsatellites. The alleles at these loci were named after the length of the PCR product. In the breed Hedemorahöna, 36 individuals were genotyped. For the microsatellite *MCW0248* the following alleles were present in this breed: *215, 219*, and *223*. The number of samples with each genotype can be seen below:
215, 215: 18 samples
215, 219: 10 samples
215, 223: 3 samples
219, 219: 1 samples
219, 223: 3 samples
223, 223: 1 samples
Calculate the allele frequencies

14. In cattle the allele for polled (having no horns), *P*, is dominant over the allele for having horns, *p*. Two polled animals that each had one parent with horns are mated to each other. They get one calf. What is the probability that the calf is polled?

15. Digger is a Labrador retriever dog. He and his littermates are the results of a mating of Fågelängens King Edward and Eaglebess Kringlan. At a closer look in the pedigree-file it is found that the maternal great grandsire of King Edward (his mother's father's father) and the maternal great grandsire of Kringlan is one and the same individual, i.e. Lichithas Blizzard (L.B.) which is an International Champion. They have no common ancestors except for L.B.

a) Draw a figure to illustrate the relatedness between the parents of Digger.

b) What is the additive genetic relationship between King Edward and Kringlan?

c) Calculate the inbreeding coefficient for Digger.

d) What does the inbreeding coefficient of an individual indicate?

e) Do you expect that Digger and his siblings will get problems with fertility and disease resistance due to inbreeding? Why?

16. A number of years ago a pig producer decided to expand the farm to also have dairy cattle. She bought two young bulls and two young female cattle on an auction. The four animals were born in different herds and can be assumed to be unrelated. The breeding of these four animals resulted in the five animals in the table below:

Animal ID	Sire	Dam
E	A	B
F	C	D
G	A	D
H	E	F
I	C	G

Now she has planned a mating between H and I that will lead to a calf named J. With these 10 animals she wants to start a breeding program.
a) Draw a pedigree for the animals A up to J.
b) The parents of J (H and I) have three ancestors in common. Identify these common ancestors by showing which paths that exist between animal H and animal I.
c) Calculate the inbreeding coefficient for animal J.
d) Do you think she has enough animals to start a breeding program? Why or why not? Do you have any advice to give for the breeding?

17. A dog named Havi got 7 puppies. Two of them (we call them Ivor and Jori) were dead at birth due to a rare disease. The pedigree for these two dead puppies are described in the table below.

Dog	Sire	Dam
A	Unknown	Unknown
B	Unknown	Unknown
C	Unknown	Unknown
D	A	B
E	A	B
F	Unknown	Unknown
G	C	D
H (Havi)	E	F
I (Ivor)	G	H
J (Jori)	G	H

a) Draw the pedigree using the information from the table above.
b) Calculate the inbreeding coefficient for Ivor.
c) Assume that the lethality in the two puppies is controlled by a single locus, which gene action do you think is involved?

18. An analysis of the genetic parameters for meat quality gave the following results. $V_A = \sigma^2_A = 4.2$
$V_P = \sigma^2_P = 14.5$.
Estimate the heritability for this measure of meat quality.

19. The litter size is registered in a population of mice. The environmental standard deviation (σ_E) is estimated to 1.5 offspring and the genetic standard deviation is estimated to be 0.8 offspring. What is the heritability?

20. The heritability h^2, of a trait is 0.3 and the selection differential, S, is 10. Calculate the response to selection, R.

21. A dog breeder of a breed that has the average height 40 cm wants to breed for larger dogs. The heritability for height in this breed is 0.6. The breeder selects a male with height 45 cm and a female with height 43 cm. What is the expected average height in their puppies?

22. Explain in a few different ways what a breeding value is.

23. In Gotland sheep the lambs get evaluated for several pelt traits when they are about 4 months old. They are scored for a few pelt traits (for example colour and curl size) and also get an overall score (where a higher value is better). The traits are used for estimation of breeding values with BLUP. In the table below are the overall score and the estimated breeding values for the overall score are listed for a six sheep that are for sale. Imagine that you have a herd of Gotland sheep and want to buy three new breeding animals. Which three would you buy?

Individual	**Overall score**	**EBV for overall score**
Sheep 1	6	108
Sheep 2	5	105
Sheep 3	6	96
Sheep 4	4	99
Sheep 5	4	106
Sheep 6	5	93

24. Use the data in exercise 11 and calculate the expected heterozygosity.

25. Use the data in exercise 13 and calculate the observed heterozygosity and the expected heterozygosity.

Answers:

1. The sperm cells contains only chromosome from each chromosome pair, i.e. if 2n=54, the number of chromosomes in a sperm cell is 54/2=27.

2. G

3. GT x GT

	G	T
G	GG	GT
T	GT	TT

¼ = 25% of the offspring is expected to be genotype TT.

4. The tortoiseshell female has genotype X^OX^o produces two types of gametes, X^O and X^o. The orange male has genotype X^OY and produces two types of gametes, X^O and Y.

	X^O	Y
X^O	X^OX^O (orange female)	X^OY (orange male)
X^o	X^oX^O (tortoiseshell female)	X^oY (non-orange male)

¼ = 25% orange females
¼ = 25% tortoiseshell females
¼ = 25% orange male
¼ = 25% non-orange male

5. The orange female has genotype X^OX^O produces one type of gamete, X^O. The black male is non-orange and thus has genotype X^oY and produces two types of gametes, X^o and Y.

	X^o	Y
X^O	X^OX^o (tortoiseshell female)	X^OY (orange male)

50% orange males

6. The female cat produces two types of games with regards to these two loci, X^Ol and X^ol. The male cat produces four different types of games: X^OL, X^Ol, YL och Yl.

	X^OL	X^Ol	YL	Yl
X^Ol	X^OX^OLl	X^OX^Oll	X^OYLl	X^OYll
X^ol	X^OX^oLl	X^OX^oll	X^oYLl	X^oYll

a) The genotypes X^OX^Oll and X^oYll are orange and have long hair. The probability is thus 1/8+1/8 = 1/4 =0.25 =25%
b) The genotypes X^OX^OLl and X^OYLl are orange and have short hair, the probabilty is thus 1/8+1/8 = 1/4 =0.25 = 25%

7. All offspring have inherited the alleles *a* and *b* from the parent with genotype *aabb*, thus the parent with genotype *AaBb* has produced 20 gametes with *AB*, 5 with *Ab*, 4 with *aB*, and 21 with *ab*. The most common combination of alleles inherited from the double heterozygous parent is *AB* and *ab*, thus these are the non-recombinant gametes. The recombinant alleles are *Ab* and *aB*. The recombination fraction between locus A and locus B is thus
r_{AB} = (5+4)/50 = 9/50 = 0.18

8. The recombination fraction between locus *C* and locus *D* is
r_{CD} = (11+9)/60 = 20/60 = 0.33

9. The frequency of an allele in a population can be altered by natural selection, mutation, migration, nonrandom mating, and genetic drift (sampling errors).

10. p=f(G)=(2*11+22)/(2*50) = (22+22)/100 = 44/100 = 0.44

q = f(T) = 1-p = 1-0.44 = 0.56

Note that it does not matter which of the allele frequencies that is p and which is q, as long as you define it and show how you have done the calculation.

11. a) AA: 5/20= 0.25
AT: 10/20=0.50
TT: 5/20=0.25
b) f(A)=(2*5+10)/(2*20)=20/40=0.50
f(T) = 1-f(A) = 1-0.50 = 0.50

12. a) 0.1*0.1= 0.01

b) 2*0.15*0.07 = 0.3*0.07=0.021

13. f(115) = (2*18+10+3)/(2*36) = (36+13)/72 = 49/72 = 0.681
f(119) = (2*1+10+3)/(2*36) = 15/72 = 0.208
f(223) = (2*1 + 3+3)/(2*36) = 8/72 = 0.111

14. Since the two animals are polled they must have at least on *P* allele. Since they have one parent with horns (that must have genotype *pp*) they also must have at least one *p* allele, thus they are both heterozygous *Pp*. The cross is thus *Pp* x *Pp*. They will have ¼ *PP*, ½ *Pp* and ¼ *pp* as offspring probabilities. *PP* and *Pp* are polled and the probability of the calf being polled is thus ¼ +1/2 = ¾ = 75%.

15.

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                    LB
               /          \
            A                B
         /                      \
      C                            D
   /                                  \
Fågelängens King Edward          Eaglebess Kringlan
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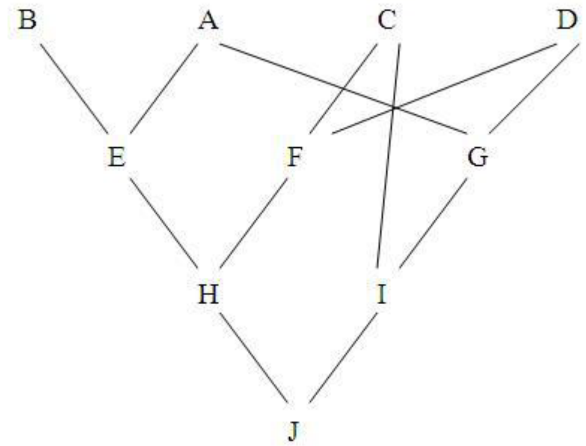
b) $a_{FE} = 0.5^{3+3} = 0.5^6 = 0.015625$ (if you assume that LB is not inbred)
c) F_D = 0.015625 /2 = 0.00781
d) The probability that two alleles in a locus in an individual is identical by descent IBD, or the proportion of loci in an indivudual where the two alleles are IBD.
e) No, the inbreeding coefficient is low.

16. a)



b) HEAGI
HFDGI
HFCI

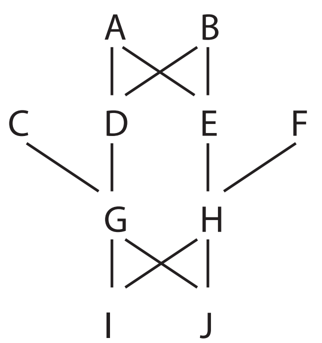
c) $F_J = \Sigma(1/2)^n(1+F_{CA})$

Where J is the animal you should calculate the inbreeding for and CA is Common Ancestors to the parents of J. In this case the parents have three common ancestors but none of them are inbred. Therefore the calculation is as follows:

$FJ = (1/2)^5 + (1/2)^5 + (1/2)^4 = 0.125$ or 12.5%

d) No, the low number of animals will lead to a rapid increase in inbreeding. She should introduce other breeding animals. If she does not want to have more animals on the farm, she can use artificial insemination and buy semen from bulls that are less related to the animals in her herd.

17. a)



b) The pedigree paths for I are: GDAEH and GDBEH, Therefore,

$F_I = (1/2)^5 + (1/2)^5 = 0.03125 + 0.03125 = 0.06250 = 6.25\%$

c) Mortality has been probably caused by a lethal allele. The fact that no mortality in the parent / grandparent generation has been reported indicates that the causal allele is probably a recessive allele.

18. $h^2 = 4.2/14.5 = 0.29$

19. The phenotypic variance $V_P = \sigma^2_P = V_A+V_E = \sigma^2_A + \sigma^2_E$

The variance is the square of the standard deviation.

$h^2 = \sigma^2_A / \sigma^2_P = 0.8^2/(0.8^2+1.5^2) = 0.64/2.89 = 0.22.$

20. $R = h^2 * S = 0.3*10 = 3$

21. The parents are on average 4 cm higher than the average in the breed
(45+43)/2 =44
44-40 = 4
Thus the selection differential, S = 4.
$R = h^2 * S = 0.6*4 = 2.4$
Thus the puppies are expected to be 40+2.4 = 42.4 cm on average.

22.
- The breeding value is a measure of the individual's additive genetic value.
- It measures how much of the phenotypic superiority of the individual that is expected to be inherited on average with regard to the trait(s) included in the breeding value.
- It is the effect of introducing the individual's genes in the population

23. sheep 1, sheep 2, and sheep 5, since they have the highest breeding values.

24. expected heterozygosity: $1- (0.5^2+0.5^2) = 1 - (0.25+0.25) = 0.5$

25. observed heterozygosity: (10+3+3)/36 = 16/36 = 0.444
expected heterozygosity: $1 - (0.681^2 + 0.208^2 + 0.111^2) = 1-0.519 = 0.481$